(The Challenge and Its Roots)

The subject of this lecture -- the relation between science, technology, and responsibility -- is very general, but the scope of my remarks is narrower, and more specific. It is an inquiry into the reasons why in recent years science and technology, which used to be the greatest sources of pride and of hope for the future, have come to be questioned by substantial and vocal groups, especially of young people. These critics look with distrust, not only upon specific applications of technology, but on the whole enterprise of science -- as the acquisition of objective knowledge and of technology -- as the power to control the forces of nature.

In the 17th and especially the 18th centuries the idea that all knowledge would automatically be applied for the good of humanity seemed to be a truism. Typically Thomas Jefferson wrote: "There is no truth that I would fear to be known." In the 19th century, technology based on the new science suddenly flourished in a most vigorous way, which provided the foundations for modern industry and led in turn to new scientific progress by a continuous positive feedback. The development of the science of electricity and of

electric power, and of chemistry as a source of new materials, seemed to point unmistakably the way to the future.

Even though the attitude of the untrained public toward science always had an element of superstitious distrust, the prevalent attitude toward technology was decidedly optimistic.

Was this optimism justified? Was the *laissez-faire* attitude of the liberal economists, with its implied assumption that developments in technology would automatically bring prosperity and eliminate war, poverty and disease, the correct philosophy for society? Is the 19th century path a royal way to perfection or is it a blind alley leading to perdition? The title I have chosen for to-night's talk -- Slippery when wet -- stands out as a clear warning in the thinking and writings of thoughtful people throughout society.

What is new today, especially among the young, is a questioning not only of the uses of technology but also of the technological direction in which human society is going, both in capitalist and socialist countries. This questioning, irrespective of its reasons and of its wisdom, serves at least one useful function. It reminds

us that, in the shaping of our culture, there is nothing automatic, nothing dictated either by prime causes or by predetermined final goals. Culture is a product of men, a product of the minds and efforts of men throughout the world and the ages. Science and technology are part of a program over which we have control and, therefore, responsibility. As expressed by the British biologist, Peter Medawar, "The bells that toll for mankind are attached to our own neck, and it must be our fault if they do not make a cheerful and harmonious sound."

What has happened to cause a change in the attitude of many people toward science and technology? A critical process, I believe, has been the shattering in this century of past illusions about the course of human progress. The first world war destroyed the illusion of an earlier generation -- the generation of my father -- that war, at least between developed nations, would disappear and that conflicts would be resolved peacefully by rational agreements. This illusion, of course, ignored the enormous injustices between rich and poor nations and the exploitation of the latter by the former. But the

first world war came as a rude awakening.

Then, just as the world was beginning to recapture the illusion of a smooth future of progress, came another shattering experience. In one of the most "advanced," "civilized" nations of Europe there arose a political monster -- a regime based on the open denial of the ideal of human brotherhood, on the celebration of race and the state and of force, and on the application of the fruits of human ingenuity to the corruption of the human spirit. This shock was even more damaging to the vision of a smooth automatic progress. For, if the realization that human institutions can go wrong is painful, the idea that human institutions can be set up in order to do wrong is intolerable.

Then, with the second world war another fateful development took place: the acceptance of mass slaughter, of the bombing of civilian populations, first in Holland and England, then in Germany and Japan, culminating in the atomic bombing of Hiroshima and Nagasaki. The atom bomb brought home to every citizen of the world the fact that a great discovery of science had been applied directly to mass

destruction even before its possibilities for constructive uses had been explored. And, even more disconcerting, the peace of the world has since then been based, not on mutual understanding, but on the balance of nuclear terror, on the realization that several governments, at enormous expense of scientific and technological resources, have equipped themselves with the capability of annihilating each other's nations -- and possibly even mankind altogether.

This brings me to another reason for the widespread questioning of the role of science and tecynology in society: the magnitude of the changes that science-based technology can bring about. The perturbations produced by technology are reaching a magnitude of the same order as the intrinsic parameters of the natural and social phenomena which they affect. Today's weapons can destroy a substantial portion of humanity. But this is only one example. Take agriculture and public health science. We know that the technology based on these sciences was increasing the production of food, improving sanitation, removing many of the traditional evils of mankind -- starvation, filth, epidemics -- and increasing life expectancy by decades.

But we were not sufficiently aware that the same technology that made our lives longer and richer and healthier was bringing about the threat of overpopulation, which may well become the number one problem facing humanity. Likewise, in our technological optimism we closed our eyes to the fact that uncontrolled use of natural resources by the industrially developed nations can bring about the exhaustion of critical raw materials, deplete world reserves, alter the environment, and make it even harder for other nations to approach a comparable standard of productivity.

But there is another reason that makes people uneasy about the wisdom of the technological path. Modern technology, while contributing unquestionable benefits to large parts of humanity, has brought about the need for ever larger, more elaborate, more impersonal institutions in order to run the technological machinery. The modern corporation, the modern state, whether socialist or capitalist, are complex machines directed to managing at some efficient level a technology that has become indispensable to the functioning of modern society. These institutions become increasingly depersonalized. The

human element seems to disappear. The average individual feels that he has less and less understanding and less control over the forces that mold the world in which he lives. Puzzlement becomes becomes discouragement and then alienation. And with alienation comes the questioning, not only of the social structure, but also of its technological foundations and, finally, of the scientific enterprise itself.

We fear that society may become committed, irreversibly and automatically, to a purely technological future. We question, not only the possible misuses of technology, from atom bombs to thoughtless pollution to the wasteful depletion of rare resources, but the very invasiveness of technological thinking, the neglect of alternative values, even the labeling of such alternative values as reactionary. The slope of our commitment to an overpowering technology is steeper and steeper. Down the slippery slope we proceed with increasing misgivings. Will the joy ride prove to be a descent into the abyss? Do we need a warning -- slippery when wet?

To illustrate concretely the change in attitude toward science

and its products I can think of no better examples than some from my own science, molecular biology. This is a very esoteric field, the study of the molecular basis of cellular functions such as the replication and the function of genes, the synthesis of proteins, the assembly of cellular membranes. We have witnessed very great progress in understanding the basic phenomena of life, the chemistry of DNA, the regulation of gene function, the mechanisms of enzyme activity. As yet there have been no practical applications of the newest knowledge; it has been as "pure" a science as some branches of mathematics. It has in fact been challenged from some quarters for its lack of relevance, that is, for its lack of explicit practical purpose. Now we begin to see the possibility of practical applications in a not too distant future. We have learned how to isolate certain bacterial genes in pure form, to transfer them from cell to cell, and even to synthesize some genes chemically. We have learned that some viruses can act, both in bacteria and in animals, as vehicles for transferring genes from cell to cell. Chromosomes or fragments of chromosomes can be introduced into living cells by

cell fusion in the test tube. As a result of these discoveries, the remote but distinct possibility exists that similar genetic intervention can ultimately be carried out in man, treating genetic diseases by correcting the genetic defects rather than only by remedying their consequences.

There exists even the distant possibility, by a combination of genetic and embryological techniques, of altering the genetic material at the hereditary level by affecting the germ cells themselves. Embryology is advancing very rapidly. It is already possible to diagnose some genetic diseases of the unborn child by examination of the amniotic fluid. It is equally possible to diagnose the sex of the unborn. Workers in Great Britain and in the United States have succeeded in fertilizing in the test tube human eggs with human sperm and in inducing the development of the fertilized eggs to the stage when they are ready for implantation in the womb. This line of research may ultimately provide a bypass for certain types of infertility and may make it possible to introduce into the fertilized egg specific genes or chromosomes. It may even make it possible to

reproduce human beings clonally, by nuclear transplantation into enucleated eggs which would then be reimplanted into foster mothers' wombs. This description of a genetic engineering still to come may sound like science finction; but science fiction has the disturbing habit of becoming reality much sooner than we expect.

Only a few years ago, the prospect of such future powers to correct the genetic constitution and even the hereditary material of human beings would have been welcomed as a promise of medical progress and of self-directed human betterment. Ant yet these very prospects have caused some people, including thoughtful ones, to raise warnings of potential misapplications. The concern is not only with the ethical problems raised by the possibility of manipulating human germ plasm or of selecting the sex of one's children. What is being feared is the purposeful creation of genetic weapons or the use of genetic techniques like nuclear transplantation to create races of enslaved morons or of ruling supermen. And when we object that these are morbid fantasies we may receive the reply that the idea of an "ultimate solution" of the Jewish problem also sounds like a morbid

fantasy, and not like the tragic reality that it was in Germany only 30 years ago.

A more subtle fear is that manipulation of human heredity for experimental purposes may weaken the respect for human personality by making it acceptable to use men as means rather than as ends -- in violation of the Kantian imperative.

I have used the example of modern biology to show how the critics of science have come to see science and technology, not as cultural advances and promises of new gifts, but as sources of new dangers. Other examples might be given from chemistry, physics, or computer science. Men are faced with what often looks to them like a blind course of technological developments. In the words of one of the great priests of that supposedly fatal process, John van Neumann: "In the field of science and technology, what can be done will be done." Is this really so? Is it wise to couple science and technology in this assertion? Science will discover what is there to be discovered. But is it necessary that every possible technology be developed? And, once developed, must it be used, irrespective

of consequences? Man revolts against the prospect of such automation. He claims for himself the responsibility to fashion his own destiny. He wants to heed the warning and, even if the way of technology is in fact the road of the future, he wants to follow it at his own pace with his eyes open, not sliding blindly down the slippery slope. But, unfortunately, in rejecting what they see as the automatic path of technological development, people often go too far: they reject all of technology and science itself as if they were the causes of the ills of society. But this is a serious fallacy. It is not the technique that generates the evils, but the way in which it is used. The problem is the uneven development of man's culture, of scientific and technical knowledge on the one hand and social institutions on the other hand. Thus technologies become available to societies that are not institutionally prepared to make wise use of them and they can become instruments to foster outdated or inhuman ideologies or tools in the hands of a soulless technocracy. The problem is not scientific or technical: it is social and political. What must be questioned is the uses society makes of the products of science the the extent to

wich it commits itself to the technological imperative as a substitute for the Kantian imperative. Yet the rejection of science and technology as legitimate enterprises of our culture has become widespread. This rejection has been expressed in provocative books such as "The Making of a Counterculture," by Theodore Roszak and "The Greening of America" by Charles Reich. These writers have challenged the validity of objective consciousness, that is, of the scientific method based on measurement and on verifiability. They proclaim instead the superior validity of subjective consciousness, as an assertion of a renewed sense of the value of the individual.

In my opinion, there are grave dangers in this attitude, which opens another slippery and treacherous slope. In exalting subjective consciousness and deprecating science and objectivity it falls into the same kind of automatic thinking that it attributes to the way of technology. It fosters the felief that, if only men as individuals would break away from the constraintes of the complex society, that society would automatically be reformed or vanish away. This is a dangerous belief which ignores the collective responsibility of

mankind to mold its own future. If society needs to be reformed, it is not going to be reformed by walking out on it. There is also a callous elitist aspect in the anti-scientific position. Rejecting technology implies rejecting the aspirations of the masses of humanity in the developing parts of the world, for whom properly used scientific technology represents the only hope for economic and social progress.

Finally, the antiscientific attitude is dangerous because it tends to become a denial of rationality itself. And if a society were to abandon reason as a guide to its policies, the result is likely to be, not the utopia of the worshippers of subjective consciousness, but the nightmare of a new irrational technocracy like that of Nazism.

This is the dilemma. On the one hand, we cannot reject scientific technology as a reality of life. On the other hand, we know that technology, while a source of great benefits, can be misused by society. And we see the danger that the machinery developed to operate modern technology may generate a powerful technocracy insensitive to human aspirations.

What is the way out? We must avoid both the slippery path of overcommitment to technological imperative and the equally slippery path of anti-rationalism. We must find means to use the power that science and technology put at our disposal in a rational way, for goals of human satisfaction freely chosen by an informed population. This will not be easy, because many of our institutions and ways of thinking -- nationalism and racism and rligious prejudice and the belief in war as an instrument of policy -- are remnants of a past that has been made obsolete by technology. We must find ways to decide wisely on how technologies are to be used -- what, when, and in whose interest. We must learn to face the future with what I might call a tensely balanced set of mutally restraining values, coupling the powers of technology to the strength of a wise humanism.

The responsibility for creating the future society rests with all mankind. But I believe that as scientists we have certain special responsibilities, because our work (even that of a molecular biologist like myself) is the source of the technology that society must decide whether to develop and how to use.

In the first place, it is important for us scientists to realize that science can never be neutral in a world that uses the products of science and that there is no value-free science, just as there is no value-free literature or value-free art. Science's purity is in the search of new knowledge to be added to the intellectual patrimony of mankind. But the acquisition of new knowledge does not necessarily absolve the scientist from asking how this new knowledge can or will be utilized. The illusion of purity and neutrality is again a dangerous path -- slippery when wet. It may obscure or even justify all sorts of compromises. It may make it easier for the least pure among the practitioners of science to cover their activities under a mantle of innocence. Yet the situation in the area of applied research is rarely ambiguous. When it comes to research on new weapons of mass slaughter few people will maintain that the scientists do not bear responsibility for the consequences of their work.

But even when applied research is not directly involved, a scientist may often have to make ethical choices in his relation

with the centers of power, the places where decisions are made concerning the development and uses of technology. He may have to choose between the attractiveness of power, the chance of influencing important decisions, the opportunity to further the applications of his own discoveries, and the risk of becoming a war asset or a partner in a technocratic machine. Is the morality of science compatible with the morality of power? For example, is the practice of science compatible with the commitment to secrecy or at least to silence? Sometimes scientists operating within the circles of power justify their activities by the belief that they can influence decisions into saner directions. But this belief is an illusion -- witness the failure of the Los Alamos scientists to prevent the atomic bombing of Japan in 1945 or the earlier failure of the British scientists to stop the futile saturation bombings of Germany -- two instances of insane warfare against masses of civilians. A scientist who associates his work closely with the centers of power is more likely to find himself a tool than a leader.

Within his laboratory a scientist has the choice of problems to

investigate, at least to the extent that he can obtain financial support. Here the questions become more subtle. To which extent are scientists responsible for the distant applications of their work, for making available to society a power that society may misuse? Should a scientist try to foresee the possible applications of his work in deciding what research he will pursue? Should he try to concentrate on problems relevant to the immediate needs of mankind or should he freely pursue the acquisition of new knowledge? Should he choose not to work on problems whose solution may generate techniques which society has not yet learned to control?

Let me take an example from recent controversy. A number of studies have raised the question of the existence of several points difference in the average IQ of black vs. white Americans. Part of the controversy has to do with technical questions of significance of the data. But there is a more fundamental issue to be raised: should such research be done at all? Some prominent scholars have asserted both in scholarly and popular articles the need to find out, either in order to devise educational reforms or in the name of

"the right to know," that is, in the interest of true science. Inquiry should not be shut off, these scientists believe, nor should society be left in ignorance. But nobody seems to have been concerned that in our society the very doing of this research and publishing its results, whatever they are, constitutes mischief. What must be balanced in this case is the right to know vs. the right to do mischief. I for one see no difficulty in choosing, especially when the "knowledge" to be obtained is of no use at all except to the researcher's career.

In other words, I believe that not all research is legitimate: its legitimacy has to be judged in terms of its predictable consequences. When it comes to working with human beings, there are curiosities that are not legitimate because they hurt. Medical research has long recognized this principle and social science needs to recognize it as well.

Leaving aside the controversial areas, there is one important function that scientists must strive to fulfill individually and collectively, and that is to try to educate the public in the facts of science, explaining new developments and their technological

consequences, so that the public may have better grounds for reaching policy decisions.

If in a well-ordered society decisions are to be made by the consensus of an informed public opinion, then it is the responsibility of those who know the facts to make them known and explain them. Too many of us live in ivory towers, publishing scholarly papers, but neglecting to make contact with the outside world or to understand the workings of the society that makes use of our scientific production.

The disaffection and even the hostility of the general public toward science is based in great part on ignorance and misunderstanding, not only of the relations between scientists, technologists, managers, and politicians in society, but also of the facts of science and, even more important, of the nature of science and of scientific discovery. The large number of American citizens, even educated ones, who believe in the reality of astrology, levitation, or extra-sensory perception is a testimony, not to credulity, but to a lack of a basic grasp of the nature of science, of the concepts of proof and verifiability. Even more relevant is the scientific

ignorance of supposedly responsible political leaders. Thus British Prime Minister Clement Attlee was quoted as knowing nothing of the genetic effects of radiation when he concurred in President Truman's decision to drop the atom bomb -- and I would be surprised if Truman knew any better!

What educated citizens should have -- and, therefore, should get in school and in the mass media -- is not so much a superficial knowledge of some physics, chemistry, geology, and/or biology as an appreciation of the method of science and of the mutual interactions between science, technology, and politics. Besides helping them make informed decisions, such an appreciation would help dispel irrational attitudes of impotent fear, or despair, or mystical worship toward science and technology. It would also counteract the rise of technocratic elites which, having (or being reputed to have) exclusive possession of the technical knowledge, tend to monopolize the direction of societal affairs.

Finally, there is another task that concerned scientists can undertake, but rarely do. This task is to be actively involved, as

citizens but also as scientists, in the affairs of the society which their work will ultimately change and even transform. This involvement, in my opinion, ought not to be limited to acting as expert consultants to government and industries. It may take the form of participation as individuals -- not institutionally -- at the political lavel where the basic decisions are or should be made. A democratic society could well use more scientists actively involved in politics, participating in the decision-making process not behind the scenes but in the heat of the political struggle. There have been some important illustrations of this. After the last world war, scientists led the political struggle that achieved civilian rather than military control of atomic energy in the United States. More recently, scientists openly entered the political dbate on the deployment of anti-ballistic missiles. In such ways scientists help society evolve in a direction that permits a wiser utilization of the fruits of science for man's benefit.

Even in areas less directly influenced by science, we scientists can be valuable participants in the political process for a number of reasons: because we are trained in the precision of measurement

and critical evaluation of data, and also because our work fosters the habit of intellectual integrity and collaborative activity in order to produce universally usable scientific knowledge.

In concluding, let me return to a very difficult question, that of pure versus goal-directed research. Should a scientist, in choosing the subject of his investigations, consider primarily the advancement of knowledge or does he have the obligation to ask himself whether his work is relevant to the immediate needs of society? There has been a rising demand for relevance in the work of scientists -- a demand that those with scientific skills devote themseves directly to eliminating urgent ills such as poverty, disease, and pollution of the environment.

These urgent tasks are very real, and many scientists in the applied areas are devoting their work to them. But not all science is applied science. We must be careful not to respond to the call for relevance either by apologizing for pure science or, worse, by camouflaging it as goal-directed science. All knowledge may find applications; but the pursuit of knowledge does not need such justification.

The sciences are not only or even primarily the handmaidens of technology. Like philosophy and the arts, they are integral and essential components of the intellectual enterprise of mankind. They are part of what makes man human, the source of knowledge of himself and of the world around him. Society may at some times support one or another branch of science for the practical benefit that it expects of it. Or it may even, as has been the case in recent decades in the United States, support the whole enterprise of science on the assumption that by-and-large the results shall be beneficial. And then, at other times, this support may be questioned for the various reasons I have discussed. But, as long as there will be young people who wonder why plants flower in spring, how an egg gives rise to a bird, why a radioactive nucleus emits beta rays -- or how all these things came to be in the first place, or where it will end -- science will continue to advance, supported or not.

It may be, however, that a sound foundation to the continuous advance of science may require from scientists a new and heightened

sensitivity to the aspirations of humanity in its struggle toward a better life. It may require the exercise of an active sense of responsibility for involvement into the social aspects of science. This may be the best way for us scientists to legitimize the pursuit of our chosen enterprise.